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UK Research and Innovation

Specification for the Supply of RF Waveguide Transports for the CLARA Linacs at Daresbury Laboratory

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Approvals:

Name	Responsibility	Position / Role	Signature and Date
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Contents

1. Introduction

1.1 STFC

Contracts will be awarded by the UK Research and Innovation Science and Technology Facilities Council (STFC). All contractual issues will be managed by the relevant authority (UK Shared Business Services Limited; UKSBS or STFC) with technical issues being the responsibility of the Accelerator Science and Technology Centre (ASTeC) and the Technology Department at Daresbury Laboratory.

1.2 Compact Linear Accelerator for Research and Applications

A next-generation light source test facility is to be constructed at the Daresbury Laboratory which will be known as CLARA (Compact Linear Accelerator for Research and Applications), shown in Figure 1. The aim of the CLARA project is to develop a normal conducting test accelerator capable of generating longitudinally and transversely bright electron bunches and to use these bunches in the experimental production of stable, synchronised, ultra-short photon pulses of coherent light from a single pass FEL (Free Electron Laser) with techniques directly applicable to the future generation of light source facilities.

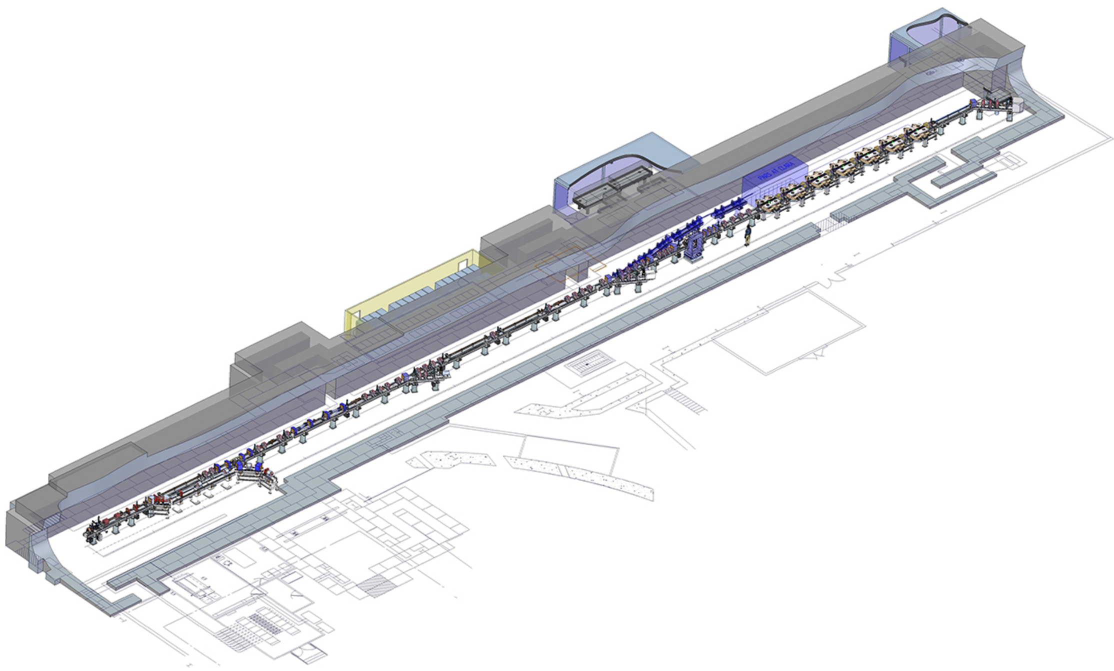

Figure 1: CLARA layout

Presently at Daresbury Laboratory the Versatile Electron Linear Accelerator (VELA), a 6 MeV machine, is being operated. As part of a complimentary programme of work the CLARA facility is being developed to provide 250 MeV electron beam. The CLARA facility is to be situated in the 'Electron Hall' located at Daresbury Laboratory and a schematic for CLARA is shown in Figure 2. The waveguide transport runs from the accelerator hall through chicane labyrinths in the concrete shielding and to the modulator klystrons which are situated on the roof space as shown in Figure 3

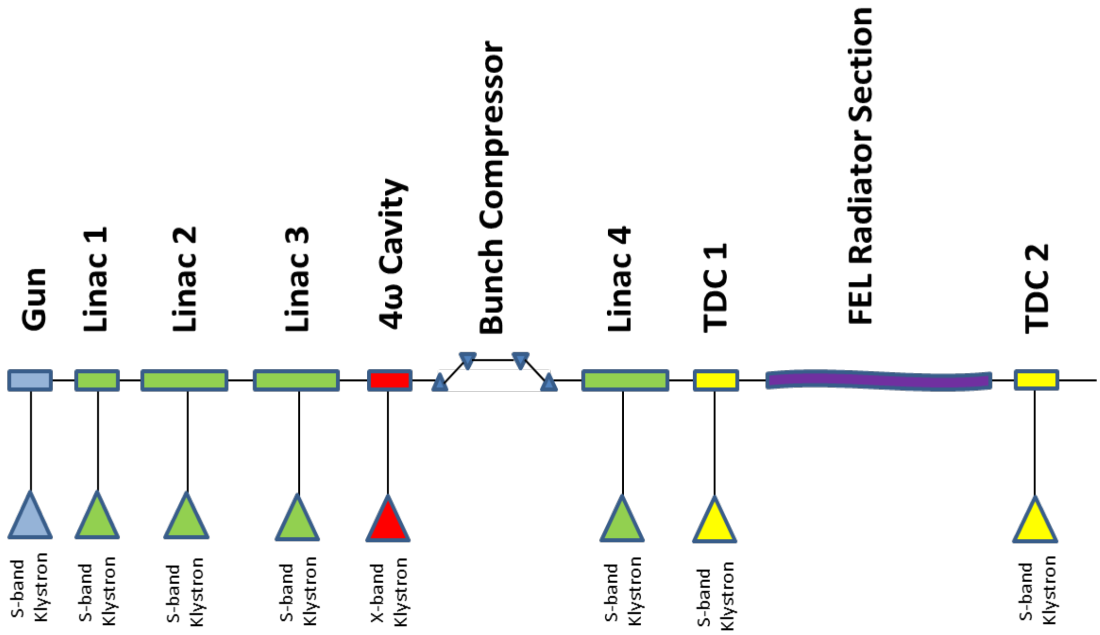

Figure 2: CLARA schematic

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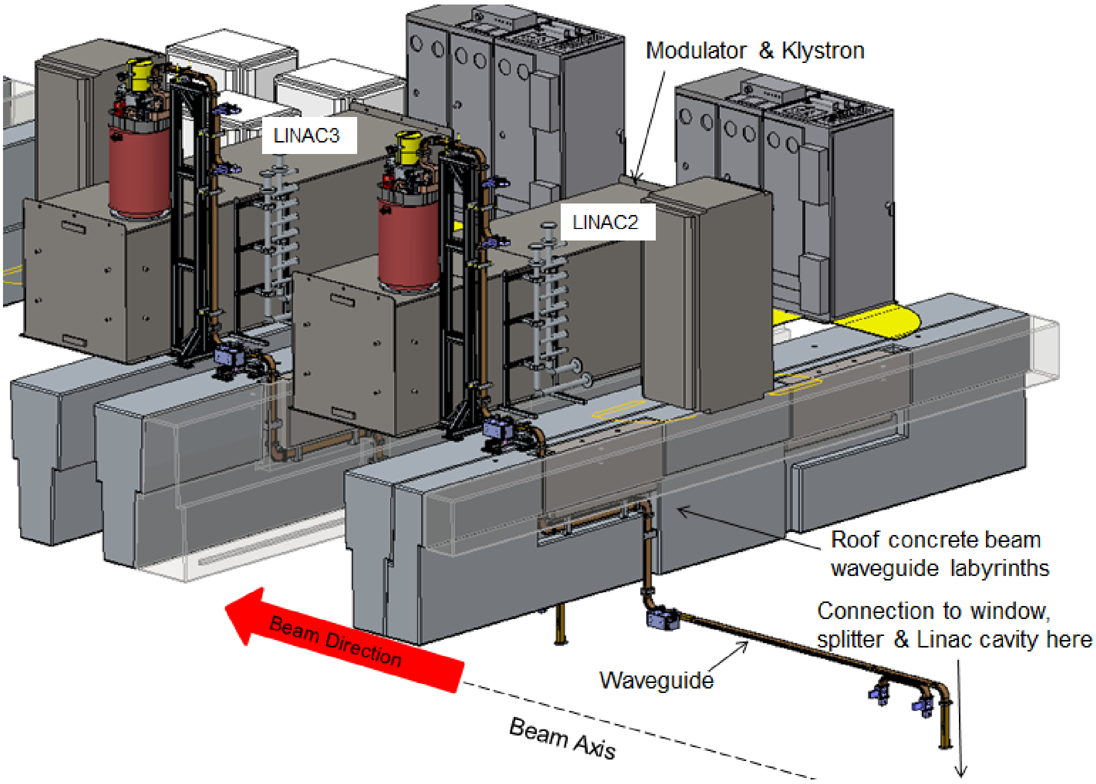

Figure 3: Illustrating context of RF waveguide run & labyrinth penetrations for Linac 2 & 3 .

1.3 Operation

The CLARA facility will be operated daily and run for long periods of time. It is planned to operate the electron test accelerator for approximately 4000 hours per year. During operational running of CLARA the linac klystron modulators will often be run at full peak power for long periods, but will also be required to operate at various peak RF power levels with different pulse duration and repetition rates, so as to provide the various operating schemes for the accelerator science to be performed.

1.4 Waveguide Requirements

STFC requires a waveguide system for the CLARA facility capable of handling RF peak powers of up to 80 MW for the 3 RF 4m linacs. These RF systems will be operated at a frequency of 2998.5 MHz with a RF pulse width of up to 3 µs and a repetition rate up to 400 Hz. However, it should be noted that these conditions may not all be required at the same time. Detailed waveguide requirements for the RF systems are defined in this document.

1.5 Specification Abstract

This specification concerns design finalisation, manufacture, and delivery, to Daresbury Laboratory, of the RF waveguide distribution system for the CLARA RF linacs along with supporting documentation. The waveguide requirement comprises of:-

1. Waveguide with the provision to ensure the waveguide has the ability to be kept temperature stable.

2. Waveguide is able to transport the peak power identified, which is expected to be using UHV compatible components with compliant flange interfaces.

3. RF water loads for the linac cavities for routine operations and testing

4. Documentation

5. Suitable gaskets (and spares)

6. Delivery to Daresbury Laboratory

Note: RF windows for these systems will be covered in a separate contract.

2. General Conditions

This document describes the technical specifications and procedures to be followed for the procurement of the CLARA RF waveguide distribution system.

2.1 Scope of Contract

2.1.1. The contract will cover the finalisation of the design with STFC, manufacture, and delivery of the CLARA RF linac waveguide distribution system at STFC Daresbury Laboratory (hereinafter referred to as STFC), Warrington as described in this specification.

2.1.2. Manufactured deliverables are as defined in 3 broad classes

a) Waveguide transports
b) Splitter system for each of the 3 off linac RF cavity structure (2,3,4)
c) Two RF loads for each of the 3 off linac RF cavity structure (2,3,4)

A complete table listing all of the supply of specific custom manufactured and/or standard parts as deliverables and the quantities are as set out in section 4 under tables 2, 3, and 4. The scope also includes all necessary design and testing – including design reviews, reports, design drawings and safe secure transport to STFC.

2.1.3. The contractor will be required to co-operate closely with STFC and its authorised representative at all stages of the contract. Final design schemes and technical issues will be resolved after adequate discussion.

2.1.4. Regular progess reporting including: monthly written reports of progress against schedule and technical status and progress to date.

2.1.5. The provision of RF power to the RF cavities has been determined by STFC and is described within this document.

2.1.6. A manufacturing warranty for the waveguide, covering all aspects of the mechanical fabrication under the Contractor's responsibility, for not less than 24 months duration after delivery of each part of the waveguide to STFC.

2.1.7. The manufacturer will be responsible for any departure from anticipated performance due to the failure to adhere to any part of this specification.

2.1.8. No change to the specified requirements is permitted without the written permission of STFC. However, if at any stage of the contract it is clear that advantage could be gained by such modification then the manufacturer is encouraged to bring it to the attention of STFC.

2.2 Sub-Contracts

2.2.1 Full details of all sub-contracts must be available to STFC.

2.3 Price and Payment Schedule

2.3.1 The price for major items is to be clearly defined within the bid at AW5.2 Price Schedule PR18144.

2.4 Timescales and Delivery

2.4.1. Timescales for the project are very important. It is envisaged that the contract will be placed 5 February 2019 and the bidder should provide the best indication of delivery based on this date. It should be noted that the latest acceptable delivery date would be 33 weeks from date of order (so anticipated to be the end of September 2019), earlier delivery would be of benefit.

2.4.2. A draft manufacturing programme is required with the tender bid and a detailed programme including all necessary acceptance tests shall be issued by the contractor within two weeks of contract placement and must be approved by STFC. This programme must contain sufficient detail to enable progress of the contract to be monitored accurately.

2.4.3. Written progress reports must be submitted to the nominated STFC Project Manager at intervals of one month during the contract by e-mail addressed to Alan Wheelhouse

2.4.4. No change may be made to the agreed programme without the written approval of UK Research and Innovation – STFC, who must be contacted immediately of any circumstances which might prevent the contract delivery date from being met.

3. RF System

3.1 Description of Requirement

3.1.1 Each Linac RF system for CLARA will consist of a klystron modulator, a klystron, a RF waveguide section, a normal conducting RF cavity, and a low level RF (LLRF) system.

3.1.2 The maximum peak RF output power is 80 MW at a frequency of 2998.5 MHz.

3.1.3 The RF will be pulsed with a pulse length of up to 3.0 µs, with a repetition rate between 1 Hz and 400 Hz.

3.1.4 Tight amplitude and phase control of the RF power into the cavities is required to ensure that accelerating voltage is maintained at a constant level and is synchronised with the electron beam. The amplitude and phase stability provided by the klystron modulator will be a key component in providing this required control.

3.1.5 During operation the output power to the cavities may be varied. This variation may be done hourly, from zero to full peak power.

3.1.6 During operation the RF pulse width may be varied from 0.25 µs up to at least 3.0 µs. This variation may be done hourly.

3.1.7 During operation the repetition rate may be varied. This variation may be done hourly.

3.1.8 The RF parameters for the Linac cavities are shown below:-

Table 1:- Parameters for the Linac cavities

Parameter	***Value***
Frequency	2998.5 MHz
Bandwidth	~ 5 MHz
Accelerating Voltage	100 MeV
Accelerating Gradient	25 MV/m
Peak RF input power	up to 80 MW
Pulse Repetition Rate Range	1 – 400 Hz
RF Pulse Width	0.25 - 3.0 µs
Amplitude stability	0.0001

Phase Stability	0.1°
Operational Temperature range	30 - 45°C
Input (linac RF window interface)	WR284 (CERN LIL flange)

4. RF Waveguide & Loads

4.1 Waveguide Layout and Components – Drawing Reference & Deliverables

4.1.1 Linac 2,3,4 Waveguide transports - Layout and Components

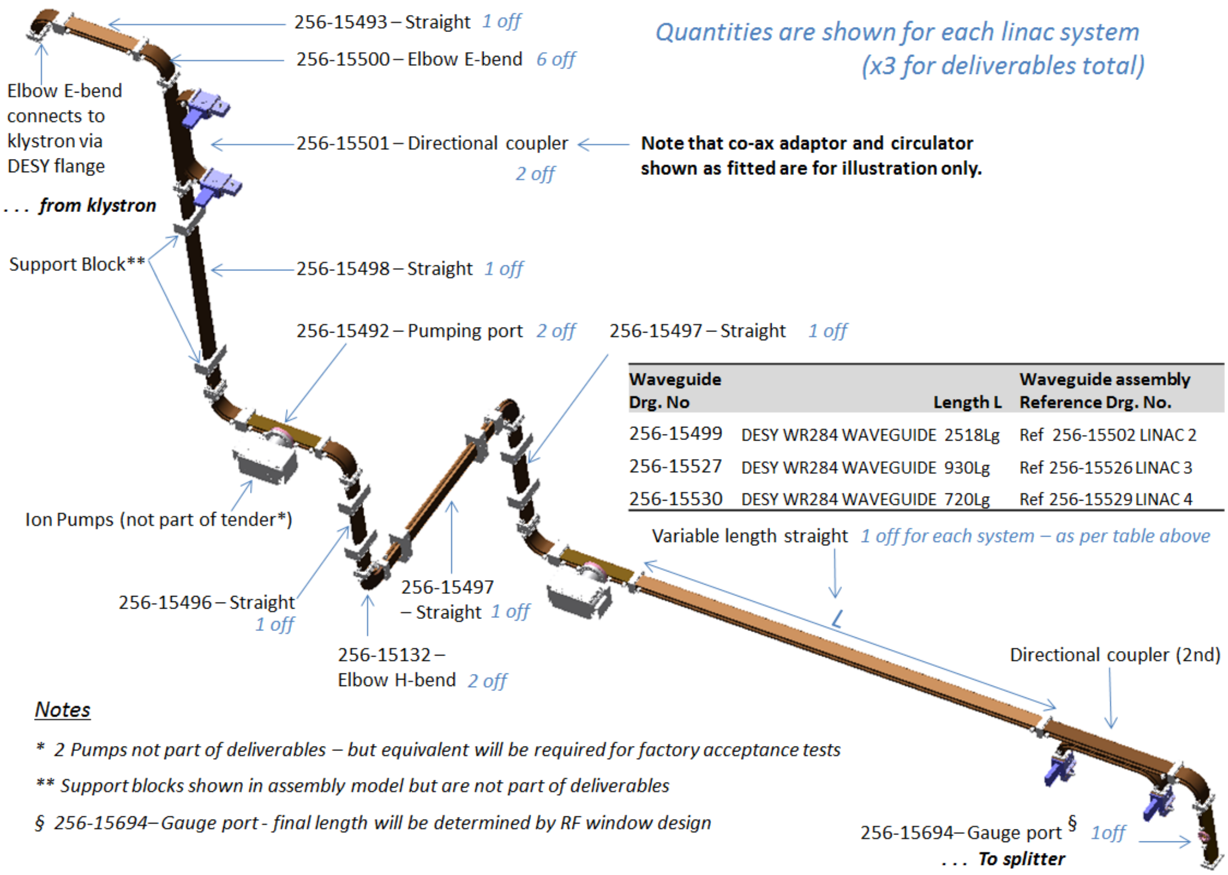

Figure 4: Waveguide Transport Illustration for Linac 2,3,4 (Generic). Quantities illustrated are per single system (system shown is Linac 2- Reference. Drg. No. 256-15502)

Defined below is a table listing the CAD drawing reference, nominal lengths and quantities required for completion of all of the Linac 2,3 & 4 waveguide transport sections.

Table 2 - Waveguide transport drawing reference and deliverables for Linac 2,3,4.

Item No.	Drawing No.	Part Description	Length (mm)	Flange Type	Qty*	Comments
Common items across all Linac 2,3,4 systems						
2.1	256-15500	E - Elbow	152.40	DESY	18	Nom. R4in. central bend
2.2	256-15493	Straight	465.00	DESY	3	Upstream spacer adds 30mm to this length
2.3	256-15501	Directional coupler (60dB)	813.00	DESY	6	Shows waveguide section only
2.4		Directional coupler (60dB) – standard parts		DESY		Co-axial adaptor & circulator – generic standard parts shown (no drawing)
2.5	256-15498	Straight	1571	DESY	3	Spacer adds 30mm to this length
2.6	256-15492	Pumping Port	465.00	DESY	6	
2.7	256-15496	Straight	720.00	DESY	3	
2.8	256-15132	H - Elbow	152.40	DESY	6	
2.9	256-15497	Straight	1165.00	DESY	3	Spacer adds 30mm to this length
2.10	256-15694	Gauge Straight	465.00	DESY	3	
2.11	256-15524	Spacers 30mm	30	DESY	18	WR284 DESY flange 30mm spacer (packer)
2.12	256-15524 [1]	Spacer 50mm	50	DESY	6	Aux 50mm spacer (packer)
2.13		DESY flange Gaskets set	-	DESY	120[2]	Sufficient to make up all 3 systems plus 1 spare
2.14		CERN-LIL flange Gaskets set	-	LIL	10[2]	Sufficient to make up all 3 systems plus spare
2.15		Blank flanges	-		TBD[3]	All necessary DESY and LIL & CF for transport
2.16		Fasteners	-		TBD[4]	All fasteners and dowels necessary – see notes
Specific to each Linac 2,3,4						
2.17	**256-15499**	Straight	930		1	Linac 2
2.18	**256-15527**	Straight	2518		1	Linac 3
2.19	**256-15530**	Straight	720		1	Linac 4

NOTES

*Qty = quantity shown in this table is total required for each component to deliver 3 complete linac waveguide RF transport systems

[1] Same drawing as 30mm spacer but 50mm instead of 30mm. These additional spacers as deliverable are required if we need to stretch transport lengths by more than anticpated upon installation

[2] Gaskets for DESY flange type – to suit waveguide size WR284 - refer to drawing 256-15129 and for CERN-LIL to be included to make up all joints plus spare for each. Estimated minimum quantity indicated.

[3] This quantity will be defined by all necessary conflat and DESY and CERN LIL for secure and transport. This number has not been defined as it will be determined by the contractors' defined specifics of the lot shipment plan and configuration.

[4] All fasteners and dowels necessary to make up entirety of 3 transports as shown should be included in deliverables. Exact numbers to be calculated by contractor and include 10% or 2 off spare capacity for each type (whichever is greater). Note that all fasteners shall all be stainless steel A4 grade type.

4.1.2 RF Splitter

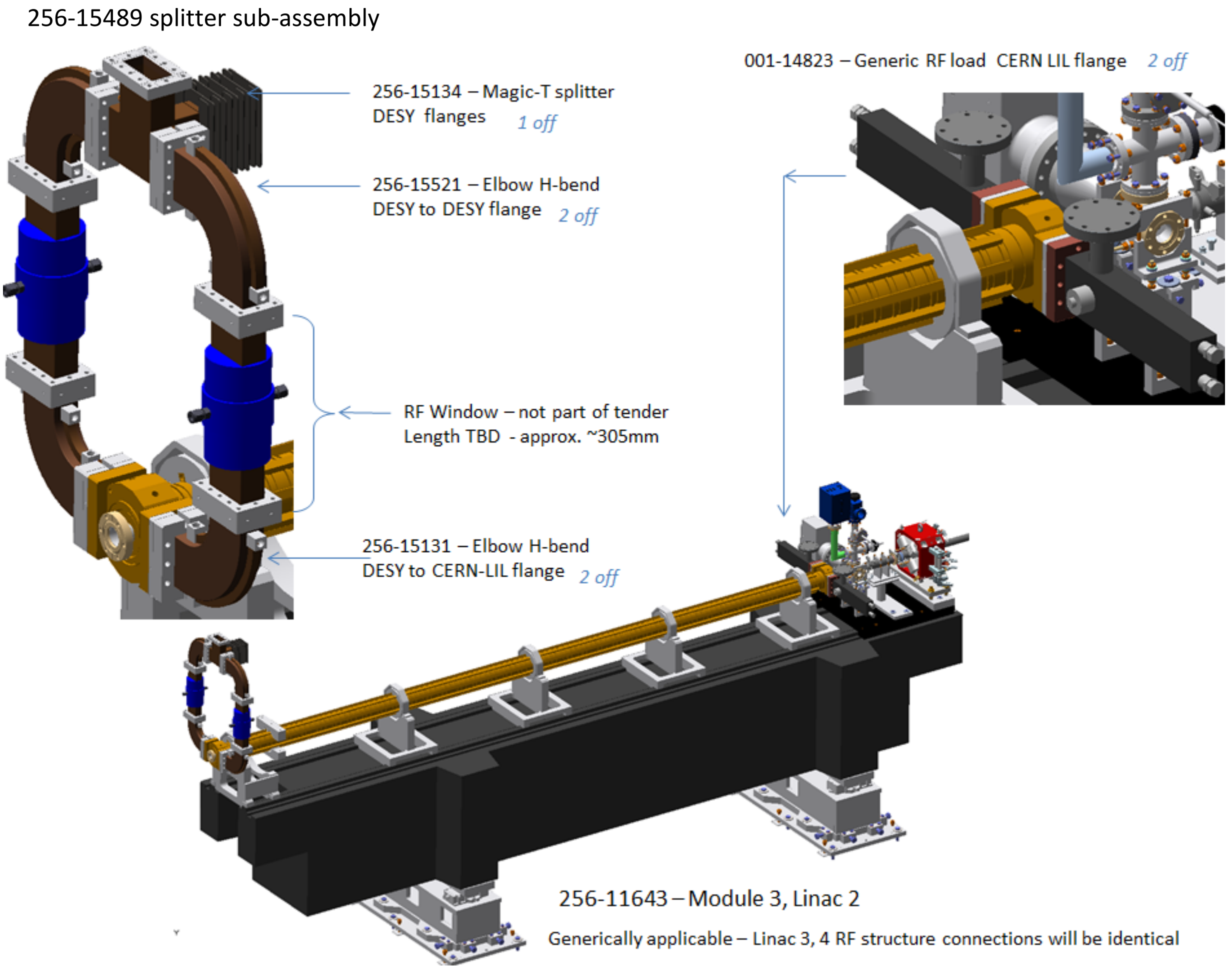

Figure 5: Waveguide Splitter & Load Illustration for Linac 2,3,4 (Generic)

See illustration Figure 5 above for reference.
Defined below is a table listing the CAD drawing reference, nominal lengths and quantities required for completion of the Linac 2,3 & 4 waveguide transport sections.

Table 3 - Waveguide Splitter drawing reference and deliverables for Linac 2,3,4.

Item No.	Drawing No.	Part Description	Length (mm)	Flange Type	Qty*	Comments
3.1	**256-15521**	Elbow H-bend		DESY/ DESY	6	
3.2	**256-15131**	Elbow H-bend		DESY to CERN-LIL	6	
3.3	**256-15134**	Splitter		DESY	3	
NOTES *CERN-LIL flange type – to suit waveguide size WR284 - refer to drawing 256-15128* *DESY flange type – to suit waveguide size WR284 - refer to drawing 256-15129*						

4.1.3 RF Loads

Defined below is a table listing the CAD drawing reference, nominal lengths and quantities required for completion of the Linac 2,3 & 4 waveguide transport sections. See also illustration Figure 6 for reference.

Table 4 - Waveguide Load drawing reference and deliverables for Linac 2,3,4.

Item No.	Drawing No.	Part Description	Length (mm)	Flange Type	Qty*	Comments
4.1	001-14823	RF load		CERN-LIL	6	

4.2 RF Waveguide Requirements

Defined below are the RF power, cooling and vacuum requirements for the waveguide.

Table 5:- RF Waveguide Specification

Item	**Parameter**
Waveguide type	WR284
Peak RF Power (MW)	80

Item	**Parameter**
RF Pulse Width (µs)	3.0
Maximum Repetition Rate (Hz)	400
Average RF Power (kW)	25
Operating Frequency (MHz)	2998.5 ± 5.0
VSWR for Operating Bandwidth	1.2:1
Insertion Loss (dB)	0.1 dB at 2998.5 MHz
Cooling	Contractor to determine and implement adequate cooling of the RF waveguide for safe operation at the rated peak and average rated power levels. All relevant details, including connector details are to be provided as part of the bid documentation. All systems shall be rated to at least 10 Bar gauge pressure and be pressure tested prior to delivery.
Flanges	DESY
Operating Vacuum Pressure	<1 x 10^{-8} mbar
Vacuum Tightness	≤10^{-9} mbar l/s (with Copper gasket)
Cleanliness Requirements	See:- spc-003-Cleaning of Vacuum Items.pdf (Attached)
Waveguide material	OFHC Copper
Water cooling interface	*To be compatible with our existing systems & practice the water connection shall be NPT ¼ " type.*
Markings	Engraved or etch drawing number to component *Alternatively an adhesive label can only be used if they can withstand highest bake temperatures*
Baking Requirements	150°C for 48 hours
Warranty	>24 months

4.3 RF Load Requirements

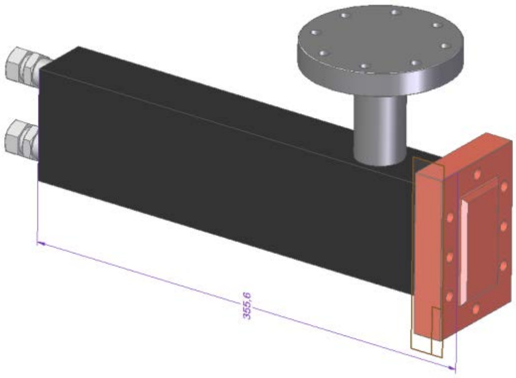

Figure 6: Generic RF Load Illustration for Linac 2,3,4 (Drawing model 001-14823)

Defined below are the requirements for the 45 MW high power RF water loads.

Table 6:- RF Load Specification

Item	**Parameter**
Waveguide type	WR284
Peak RF Power (MW)	45
RF Pulse Width (µs)	3.0
Maximum Repetition Rate (Hz)	400
Average RF Power (kW)	25
Operating Frequency (MHz)	2998.5 ± 10.0
VSWR for Operating Bandwidth	1.05:1
Insertion Loss (dB)	0.1 dB at 2998.5 MHz
Cooling	Contractor to determine and implement adequate cooling of the window for safe operation at the rated peak and average rated power levels. All relevant details, including connector details are to be provided as part of the bid documentation.

Item	Parameter
Flanges	CERN-LIL (Bottom)
Operating Pressures	< 1 x 10^{-8} mbar
Vacuum Tightness	≤10^{-9} mbar l/s (with Copper gasket)
Cleanliness Requirements	See:- spc-003-Cleaning of Vacuum Items.pdf (Attached)
Waveguide material	OFHC Copper
Water cooling interface	Compression type hose fittings – Swagelok or equivalent or ¼" NPT type
Markings	Engraved or etch drawing number to component *Alternatively an adhesive label can only be used if they can withstand highest bake temperatures*
Baking Requirements	150^{o}C for 48 hours
Warranty	>24 months

4.4 RF Splitter Requirements

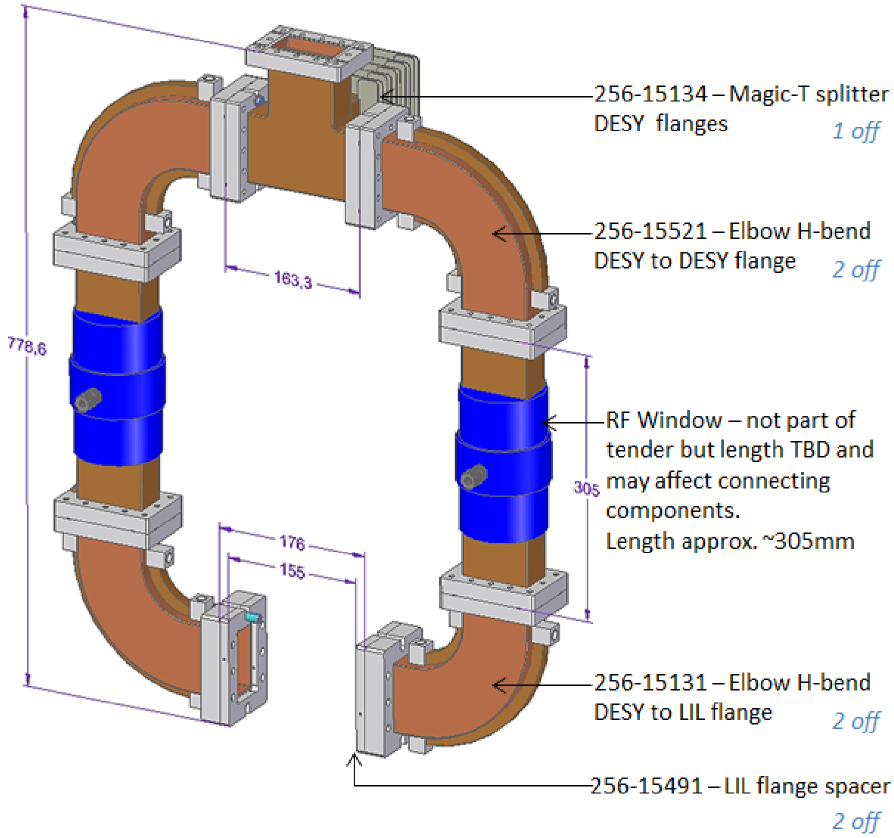

Figure 7: Waveguide Splitter Illustration for Linac 2,3,4 (Ref. Drawing model 256-15489)

Defined below are the requirements for the 80 MW high power RF splitters.

Table 7:- RF Splitter Specification

Item	Parameter
Waveguide type	WR284
Peak RF Power (MW)	80
RF Pulse Width (µs)	3.0
Maximum Repetition Rate (Hz)	400
Average RF Power (kW)	25
Operating Frequency (MHz)	2998.5 ± 10.0
VSWR for Operating Bandwidth	1.05:1
Collinear amplitude unbalance, max (dB)	0.07
Collinear phase unbalance, max (dB)	1^{o}
Insertion Loss (dB)	0.1 dB at 2998.5 MHz
Cooling	Contractor to determine and implement adequate cooling of the splitter and load for safe operation at the rated peak and average rated power levels. All relevant details, including connector details are to be provided as part of the bid documentation. All systems shall be rated to at least 10 Bar gauge pressure and be pressure tested prior to delivery.
Flanges	DESY (Top), CERN-LIL (Bottom)
Operating Pressures	< 10 10^{-8} mbar
Vacuum Tightness	≤10^{-9} mbar l/s (with Copper gasket) Vacuum leak rates and outgassing performance same specification as per waveguide transports.
Cleanliness Requirements	See:- spc-003-Cleaning of Vacuum Items.pdf (Attached)

Item	Parameter
Waveguide material	OFHC Copper
Water cooling interface	*To be compatible with existing systems & practice the water connection shall be NPT ¼ " type.*
Markings	Engraved or etch drawing number to component *Alternatively an adhesive label can only be used if they can withstand highest bake temperatures.*
Baking Requirements	150^{o}C for 48 hours
Warranty	>24 months

5. Design, Construction & Testing

5.1 General Design Tolerances, Finish & Materials

The top level design is captured within the drawings supplied with tender (refer to full listing in appendix A) and the specifications tables and notes above. In addition the following specifications also apply

5.1.1 Bulk Materials and Coatings

It is envisaged that waveguide rectangular tube section will be solid copper OFHC grade and the end flanges are mostly DESY type of stainless steel of 304 or 316 grade. The internal faces of the stainless steel shall be copper coated (see below).

5.1.2 Wall Thickness and Section Dimensions

The walls of the waveguide tube are specified as 3.175mm (1/8 inch) thickness. Different wall thickness may be used but for anything smaller the Contractor must demonstrate that under atmospheric to vacuum pressure loading during pump down cycle (or typical daily pressure variation) the walls will not flex to an extent that would affect tuning of the waveguide.

The section dimensions for waveguides and flanges are as shown on supplied drawings and are derived from international standards for WR284 waveguides - BS EN 60154. Any deviation or changes in dimensions or concession on tolerances can only be accepted or implemented after express and clear written authorisation from STFC Daresbury. By default the dimensions and tolerances shown must be adhered to.

5.1.3 Braze Joint

The joint between stainless steel flange and copper body shall be brazed in vacuum furnace to ensure that vacuum cleanliness and low outgassing performance on the internal vacuum walls can be maintained. Alternatives to brazing involving more exotic techniques such as diffusion bonding may be proposed but will be accepted only if vacuum and RF performance characteristics can be guaranteed and only after written agreement with STFC.

Details of the brazing/bonding method and filler metal should be specified in the tender return.

5.1.4 Flange Design and Gaskets

DESY flange - Our flange drawing – ref 256-15129-A - for WR284 DESY type vacuum flange follows all design features and tolerances as defined in original standard DESY Zeuthen design (Ref drawing PI-DIA-26.2.024 TDS Adapterflansch-17.5). However, STFC and Contractor must agree on all design details on flange before committing to manufacture and this shall be done during first design review. This also applies for suitable gasket. (Note that no gasket drawing is supplied with tender - this will be agreed at the design review)

LIL flange – 256-15128-A indicates our preferred LIL flange design (based on the original CERN design). We especially note that the vacuum sealing face must be lapped or polished to Ra ~ 0.05 in order achieve reliable sealing.

5.1.5 Flange Fastening and Dowels

Flange Fastening - Slots instead of holes are likely to be required on the short side of the DESY flanges in order to allow bolt/nut extraction from the side (and thereby avoiding clash with the cooling connection block if extracting lengthwise). However this detail is advisory only and not mandatory as final configuration for fastener access may be subject to the Contractor's proposed design for cooling runs.

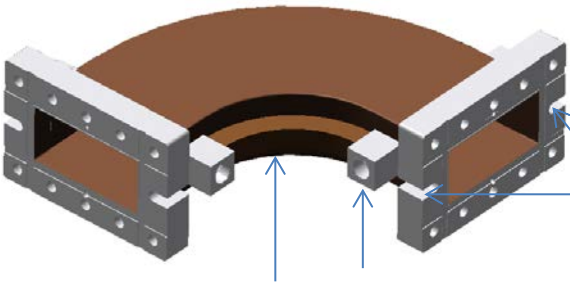

Figure 8: Flange fastener slot for side access of fasteners – illustrated for H-bend. Also illustrates cooling connection block and envisaged cooling channel runs (advisory only)

Dowels -The engineering drawings provided do not show dowel locations between flanges. Flange alignment mismatch has been the cause of breakdown in systems at STFC and so it is important that the flanges can be reliably and consistently fastened together with minimum effort and maximised precision. We require a precision and repeatability of alignment of ~ < 0.1mm and envisage this is best achieved by precision dowels drilled and reamed when adjacent components are aligned and fastened as a complete assembly.

For the DESY type WR284 waveguide flange this alignment is achieved by 2 x Ø3.2 mm holes that facilitate the precise insertion of round end dowel pins and form the alignment between adjoining flanges and also set the gasket in place . The LIL flange interfaces to the linac and RF loads do not indicate dowel alignments for the RF. Proposals for a jig fixture which aligns on external edges of the flange may be proposed as alternative to dowel pins. However, in this case the contractor must provide clear evidence of reliability and precision in working systems. The final decision will be by STFC and only after written agreement. Details of flange interface alignment will be discussed and agreed during the first design review meetings, which is expected to be within 1 month after contract award.

Fastening Torques – Contractor shall advise on their preferred torque pre-set levels to establish pre-load necessary for reliable and consistent vacuum sealing and RF integrity for all DESY and LIL flange interfaces. Suppliers may provide advice regarding fastener type, finish and any lubrication or locking nuts . As a baseline all fasteners shall be by default 18/8 stainless steel A4 grade and a minimum of 70 strength class.

Contractors shall supply all fasteners necessary to make up all the joints throughout the entire waveguide runs.

5.1.6 Surface Finish and Coating (RF /Vacuum, Internal)

By default, coating of the internal faces (RF and vacuum facing) of each stainless steel flange shall be 8 to 10 microns copper plate with ~5µm base of Nickel to assist adherence. Contractors may propose alternative coating applications and different bases but the top coat must be of high purity (>99.9%) copper and be of minimum thickness within the range as indicated.

All coating and all internal vacuum surfaces to be entirely free of visible defects such as pitting, cracks and indentations. There should be no pits or trapped bubbles visible in the copper coating.

Surface finish roughness on internal RF load facing walls shall be equivalent to ~ Ra 0.8µm (N6 ISO grade) (i.e. equivalent to datum precision machined surfaces and borderline on ground finish). This finish shall apply especially at the critical flange interfaces. In some cases, more relaxed tolerance ~ Ra 1.6µm (N7 grade) may be permitted - but this will be only after written agreement and after design review discussion.

5.1.7 Joint Step

The braze joint between flange and body tube has been set as high tolerance in terms of dimensions and step alignment at +/-0.1mm. An example illustration of the tolerance control is shown below (Figure 9). This step/flatness at the joint applies to the bulk materials and any braze filler material that potentially has migrated through this joint via capillary action during the braze process, i.e. this should not stand proud of the joint.

If suppliers believe that this particular tolerance is excessive or difficult to achieve they must be able to state what tolerances they will achieve and also demonstrate with sufficient evidence that high power RF breakdown will not occur using their proposed more relaxed tolerances (i.e. whilst operating with the RF power parameters and vacuum conditions we have specified for the system). This should be stated and specified at tender return stage.

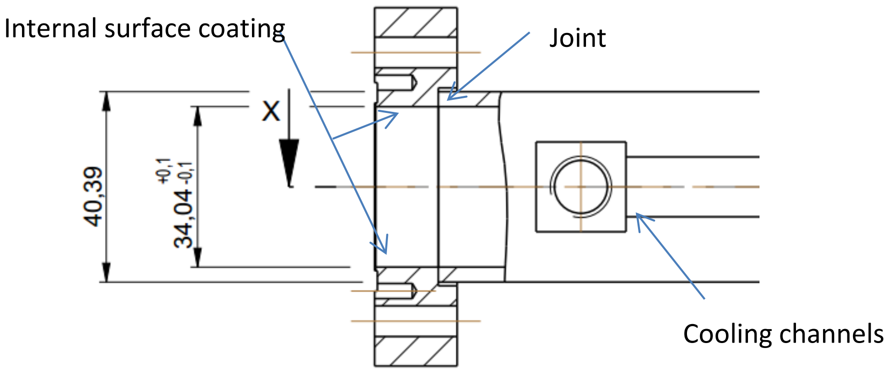

Figure 9: Flange to waveguide body joint and finish

5.1.8 Cooling Channels

Cooling channels are envisaged as either copper alloy (brass) soldered or stainless steel brazed onto main body.

Cooling channel diameter is not envisaged to be critical and with average power and expected losses being low - the cooling channels are for thermal stabilisation as opposed to providing large heat sinks.

Note that water fitting connection must be made into the channels. To be compatible with our existing systems installed on CLARA these should be ¼" NPT. Details of design should be fixed and agreed at the first design review.

5.1.9 Elbow

Radii of elbows – Nom. Centre radius 101mm (4inch) elbows are shown in the designs provided . These are consistent with previous WR284 waveguides at DL and show no particular high losses. We note that simulation results we have undertaken do not show any particular great sensitivity to dB losses vs radii. However any deviation from this agreed radii must be by written agreement and shown explicitly on the approved drawings prior to any manufacture stage. Cheaper fabrication options such as sharp 90 degree mitre corner elbows are not to be used (i.e. the elbows should be angled sweeps of agreed radii)

5.1.10 Splitter

Splitter as is shown in our concept design (Figure 7) consists of standard elbows bends and a magic Tee in centre. It is possible that the upper section (i.e. above the RF windows) consisting of two elbows and the Tee section could be combined into one component. This should be agreed during design review and the drawing and manufacture of the end flanges in terms of location and angle should be made with overall similar tolerances (or better) to that comprised from multiple component assembly.

5.1.11 External Paint / Coating

To protect against long term tarnish/corrosion on the outside of the copper body of the waveguide the component should be painted or otherwise coated in some protective adherent layer. The paint shall be high quality and adherent (e.g. epoxy powder coat) applied only on the outside surfaces. The end flange surfaces or internal vacuum surfaces shall at no point be coated by any paint and care should be taken so that the paint shall not enter any fastener holes on the flanges. A distance of 2-5mm around any hole - to clear any bolt, nut or washer used to fasten the flanges - shall be unpainted. Details of the paint and of colour shall be agreed at design review. By default waveguide colour is black at STFC.

5.1.12 Tolerances

Baseline tolerances are defined in the drawings provided and also within generic summary in listed below. In some instances the Contractor may be able to demonstrate to the satisfaction of STFC that certain tolerances are unnecessarily high to achieve the RF specification (and/or difficult to achieve). Within a framework of reasoned argument and evidence provided, an agreement may be reached that certain tolerances may be relaxed. However, it is important to note that such agreement must be specified at the time of tender and formalised as written agreement between Contractor and STFC. Note that if default tolerances are not accepted at time of tender submission without offering alternative then this could reduce scoring or even disqualify.

The final approved drawings should show all the agreed tolerances

General Tolerances:

- Inside dimensions: ± 0.1 mm
- Flange Flatness: ± 0.02 mm
- Flange parallelism (between either end) : 0.2 mm
- Flange perpendicularity to main waveguide axis: ± 0.2 mm
- Waveguide straightness 1 mm
- Twist of waveguide tubing: 5 minutes (maximum)
- Twist of flanges with respect to each other: 5 minutes (max) for length of 4 m
- Length tolerance: greater of ± 0.5mm or 0.05% x specified length
- Bow of the waveguide < 0.1% of the length
- Inside step between flange and waveguide body ~ ± 0.1 mm
- Copper coating thickness 8 – 10um

5.2 Design Review, Drawing & Documentation Control

5.2.1 Design Review

Within one month of the submission of the design report, a design review meeting shall be held with the Contractor at STFC. At this review, the Contractor will present in detail their plan for the execution of the contract, a Quality Assurance plan, the proposed design solution and a list of interfaces with the other parts of the RFDS. STFC and the Contractor must agree that the solution proposed is suitable and can proceed for manufacturing. The design report shall be updated according to the decisions agreed on, during this meeting.

During Design review, the Contractor shall provide STFC with the risk register for the design and construction of the equipment. The required mitigations shall also be provided. A hazard analysis must also be included.

A set of minutes will be produced by the Contractor following the meeting, accurately recording the agreements and actions, and sent to STFC for approval

Design shall be submitted to STFC for approval within one month after notification of the contract. STFC will give its approval or refusal, in writing, within one month following the date of the design review meeting. This design report shall include:

1. A drawing of the mechanical layouts;
2. Complete list of parts;
3. Where relevant, data sheets of the main components and subsystems, including the performance;
4. Demonstration that the components will meet the specifications;
5. A detailed Gantt chart, showing the schedule for the procurement of materials, manufacturing, factory acceptance testing and delivery

5.2.2 Progess Meetings

A programme of technical and progress meetings will be agreed between the Contractor and STFC during the Design review meeting. These should take place at least every month and may take place via a remote connection.

5.2.3 Design Approval Prior to Manufacture

Unless otherwise agreed in writing, STFC must approve the final design report before the Contractor proceeds to ordering of any materials, components or equipment required to fulfil this contract and equipment manufacture shall not start without STFC's written prior agreement on the design.

5.2.4 Drawing Provision

A complete set of drawings in pdf, dxf and STEP file format should be considered part of the deliverables. The drawings do not have to show commercially sensitive or proprietary manufacture information – but must show all tolerances, dimensions clearly along with designated material, coatings and finishes.

To minimise effort and facilitate the integration of the designs into Daresbury STFC drawing register it is envisaged that STFC drawing numbers as indicated in the tender assemblies will be used by the Contractor. A dual number system may used to facilitate working within the system of the Contractor. Details of the system will be agreed during initial design review stages. Note that a STFC Daresbury drawing sheet format template is provided in dxf form.

5.3 Acceptance Tests & Inspection

5.3.1 Factory Acceptance Tests

STFC reserves the right to carry out regular and/or spot inspections at the Contractor's premises and where deemed necessary that of its subcontractor. Contract inspections concern all contract compliance issues including schedule and quality performance.

STFC reserve the right to be present to witness any tests carried out at the Contractor's or any sub-contractor's premises.

None of the components shall be delivered to STFC Daresbury before undergoing and satisfying the following 'Factory acceptance tests'

Vacuum Checks

1. Leak test to ASTEC-VAC-QCD-spc-0004.
2. Vacuum acceptance tests to section 9 of ASTEC-VAC-QCD-spc-0005
3. RGA qualification shall conform to Appendix 2 of ASTEC-VAC-QCD-spc-0005 for the UHV vacuum region

Dimensional, Mechanical and Inspection Checks

4. A range of dimensional tolerance checks. The length, straightness and parallelism of end flanges shall be noted and recorded for each waveguide component. A range of additional 'dipstick' checks recording other dimensions of particular components will be agreed between STFC Daresbury and Contractor during design review – but additional adhoc measurements may be requested at any point.

5. All coolant fittings and channels to be test to 10Bar gauge flow and pressure drop measured and recorded.

RF Tests for Waveguide Sections

6. The waveguides of each length shall be tested with a network analyser to ensure it meets the return loss and insertion loss requirements in Tables 5, 6 and 7.
7. Directional coupler coupling and reflectivity measurement tests.

QA Test Certification

Note that the Contractor will maintain Quality assurance documentation associated with and traceable to each component delivered. All the tests results outlined above shall be recorded on the QA certificate and signed off and dated before despatch. A copy of the QA certificate including all test data shall accompany each delivery.

In some cases concessions may be allowed for specific tests that do not meet full specification but that are deemed acceptable by STFC Daresbury. In these cases however the concession must be clearly and unambiguously stated on the QA certificate log and must be agreed in writing beforehand with STFC Daresbury that the concession is allowed and within acceptable limits.

5.3.2 Site Acceptance Tests

Acceptance tests will be carried out at STFC Daresbury on selected items to establish that the equipment meets the specification and that no damage or changes have occurred during transport. These tests will be performed within 1-2 months of arrival. Any equipment shown to be non-compliant may be shipped back to the Contractor for remedial action as agreed.

5.4 Warranty and Quality Assurance

5.4.1 The terms of the warranty, which the manufacturer proposes to apply should be stated in the tender. The manufacturer must guarantee the equipment against failure due to either faulty components or manufacture. The warranty will be 24 months or greater from the delivery of the equipment. Please confirm in your bid, but note that a longer warranty would be advantageous.

5.4.2 Any other warranty statements that apply as part of the tender should be clearly defined within the tender documentation.

5.4.3 The Contractor shall maintain and apply a quality assurance program compliant with ISO-9001 or equivalent for the design, manufacture and testing of all systems and equipment provided by them. CE or equivalent marking of equipment should be applied wherever required.

5.5 Transport

5.5.1 Following the final vacuum test at the contractor's premises, all blanking flanges must remain on the vessel. The vessel is to be let up from vacuum with dry nitrogen (dew point < -70°C) and the port used for connection to the leak detector and/or pumps is to be blanked off with a flange and gasket.

5.5.2 A number of components may be fastened together into built up assemblies for ease of transport under sealed dry nitrogen conditions and to minimise number of gaskets/ flanges required. However such assemblies should not become unwieldy or unfeasibly large to transport or handle upon delivery.

5.5.3 All shipments should arrive with a full inventory list of contained parts within the shipment (i.e. all drawing numbers listed). The contractor shall retain a master list of items pertaining to the contract which can be called on at any time by STFC Daresbury to indicate items already shipped or in transit (along with shipment number and scheduled delivery date) and equally show outstanding items that have not yet shipped

5.5.4 All shipments should include QA test certificate for each component within the shipment – as outlined under section 5.3 Testing.

5.5.5 Each individual component must carry a clear and unambiguous label outside the protective wrap or packaging enabling quick identification upon delivery and allow for intermediate storage without fully unpacking the item. This label is in addition to the permanent identification marks or labels that each component carries as defined under mechanical design section.

5.5.6 Components and assemblies must be protected during storage and carriage in such a way as to prevent movement due to any vibration, shock or knocks during transit. If any evidence of component damage due to vibration shock in transit is apparent upon delivery then STFC Daresbury reserve the right to review the packaging and delivery methods and also ask for tiltwatch and/or shockwatch indicators to be fitted to all subsequent shipments.

5.5.7 All components and assemblies to be transported in such a way as to allow adequate access of handling equipment. Details of packing and required handling equipment to be approved by STFC before delivery. All packaging will be retained by STFC unless agreed otherwise.

5.5.8 Prior to final sealing up of containment for transport (pallet/ crate…etc) a photograph of the contained parts and/or assemblies in a sealed and 'ready to ship' state should be captured and sent to STFC prior to dispatch.

5.5.9 **Important:** None of the contract deliverables shall be despatched for delivery to Daresbury laboratory until both the following conditions have been met;

a) Final drawing of deliverables have previously been received and accepted in writing by STFC

b) The RGA report & vacuum test data have been submitted and approved in writing by STFC.

c) All associated RF measurement of attenuation, reflectivity, VSWR and coupling are completed and approved in writing by STFC.

Appendix A

Mechanical Drawings & Format types provided with Tender

A list of Mechanical Drawings & Format types provided with Tender to assist with assessing requirements. Not every component drawing is provided as a detail drawing as much information is generic and common and/or otherwise accessible from within the general assemblies.

Table A1: - A List of mechanical drawings provided with tender

Assembly & Top Level Drawings				
Item No.	**Drawing No.**	**Assembly Title**	**Comments**	
1	256-15502	Linac 2 waveguide assem	Shows complete assembly of waveguide system for linac2 – generically applies to linac 3 & 4 but with different final straight lengths	STP,edz, dxf,pdf
2	256-15489	RF splitter assembly	Connects from waveguide to accelerating linac structure. Note that RF windows – drawing 256-15133 - ***do not*** form part of tender.	STP,edz,dxf, pdf
3	256-11643	Linac 2	Linac 2 accelerating structure full module - complete assembly with splitter included - *for context illustration purposes only.*	STP,edz,dxf
4	001-14823	RF loads	Generic RF load on Linac 2, 3, 4 – shown for flange interface definition plus advisory illustration purposes.	STP, edz
Part Drawings - common components across all Linac 2,3,4 systems				
Item No.	**Drawing No.**	**Part Description**	**Comments**	**Drawing format**
1	256-15500	E - Elbow	Shows dimensions and tolerances of generic E-elbow	dxf,pdf
2	256-15132	H - Elbow	Shows dimensions and tolerances of generic H-elbow	dxf,pdf
3	256-15493	Straight	Indicates tolerances of generic type straight section. Specific lengths for each straight are as per table and as per assembly drawings	dxf,pdf
4	256-15501	Directional coupler (60dB)	Waveguide part of directional coupler – does not show RF component assembly	dxf,pdf
6	256-15492	Pumping Port	Indicates details of pumping port	dxf,pdf
11	256-15694	Gauge Straight	Indicates details of gauge port	dxf,pdf
	256-15524	Spacers	Indicates dimensions, tolerances & details of 30mm spacer. Same tolerances will apply for 50mm spacer	dxf,pdf

Other components				
	256-15129	DESY flange	Shows tolerances of generic DESY flange required. Shown with copper plate specification (Original reference drawing 13/7/12 DESY Zeuthen PI_DIA-26-2.024)	dxf,pdf
	256-15128	LIL Flange	Shows tolerances of generic CERN LIL flange.	dxf,pdf
	256-15491	LIL spacer	CERN LIL flange spacer piece.	dxf,pdf

Drawing Access

Drawing set pack attached with the tender in zipped format – filename;
1168-rf-spec-0001_Tender_Drawing_Pack_Complete_v1.zip

The complete set is also temporarily located on website for the duration of the tender;
http://www.eng.dl.ac.uk/secure/general/barry_fell/256%20CLARA/Drawings%20(drg)/2018-05-30_rf_wguide_ph2/